US Army Corps of Engineers
St. Paul District

UPPER MISSISSIPPI RIVER NINE FOOT CHANNEL PROJECT & HABITAT REHABILITATION AND ENHANCEMENT PROJECT ENGINEERING AND DESIGN

MISSISSIPPI RIVER
SHORELINE STABILIZATION DESIGNS
1987 to 1996
U.S. ARMY CORPS OF ENGINEERS, St. Paul District

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INTRODUCTION - Information on St. Paul District shoreline stabilization designs used on the Mississippi River is summarized in this document. This information is based on stabilization jobs constructed between 1987 and 1996. For more information, contact Jon S. Hendrickson at Phone:651-290-5634, FAX:651-290-5841, Internet:Jon.S.Hendrickson@mvp.usace.army.mil, or Address: U.S. Army Corps of Engineers, Army Corps of Engineers Centre, 190 5th St. East, St. Paul, MN 55101-1638.

CURRENT DESIGN - Shoreline stabilization designs currently used are listed below and are shown on the attached figure.

- 18-inch graded riprap, max. slope = 1V:2.5H, with geotextile
- 32-inch graded rockfill, max slope = 1V:1.5H, no filter
- Rock groins
- Offshore rock mound
- Rock Wedge
- Rock/Berm/Biotechnical
- Biotechnical

A combination of hydraulic, geotechnical, and constructability factors are considered in choosing a design. The primary design factors are the erosion process (river currents and/or waves), nearshore bathymetry (deep or shallow), and whether the site is accessible by marine plant.

DEFINITIONS:

Natural Shoreline - Shorelines of natural river islands and river banks.

Artificial Shoreline - Shorelines of manmade islands, dikes, dredge material placement sites, etc.

Erosion Process - River currents are usually the primary erosion process affecting shorelines along channels, while wind driven wave action is the dominant process for shorelines in large backwater areas. A combination of the two processes affects most sites on the main channel. Waves created by recreational and commercial boat traffic affect most sites, but is rarely the primary erosion process. Tow propwash and ice action, either from freeze thaw expansion of ice sheets (ice jacking), or during spring breakup are significant forces that must be dealt with on a site specific basis.

Nearshore - For engineering and design, the nearshore is the band of shoreline between the average water line and a line 50 feet offshore of the average water line. Nearshore bathymetry is considered shallow if water depths are less than 3 feet, and deep if water depths are greater than 3 feet.

Marine Plant Access - Marine plant access is assumed if a rock barge drafting 6 feet of water can get within 100 feet of the shoreline, and if an equipment barge drafting 4.5 feet can be positioned between the rock barge and the shoreline.

Average Water Surface Elevation (Avg. W.S. EL.) - is based on stage - duration analysis. The Avg. W.S. EL. is not equal to Low Control Pool, although in the lower ends of many pools, the two values are similar.

Rock Slope - The side slope of the rock structure (vertical rise versus horizontal run). For offshore rock mounds, the back slope corresponds to the side facing the shoreline and the front slope corresponds to the side facing the water body.

Rock Height - Height of rock above the Avg. W.S. EL. (feet)

10-YR FL. Height - Height of the 10-percent chance flood above the Avg. W.S. EL. (feet)

T - Thickness of revetment layer (inches)

Groin - Long linear rock structure placed perpendicular to shoreline to stop erosion.

Groin Length - The length of the groin measured from the shoreline. Usually groins are keyed into shoreline 5 to 10 feet.

Groin Spacing - The distance between centerlines of groins.

DESIGN PROCEDURE

The following design procedure has been used to determine the type of bank stabilization that fits a given site best. Standard hydraulic and geotechnical design procedures are used to determine rock thickness and gradation.

STEP 1 - Preliminary erosion assessment. On natural shorelines a past history of erosion has usually been established through local observation. If available, aerial photographs from different time periods should be used to verify local observation and possibly establish an erosion rate.

STEP 2 - Field reconnaissance of the site should be done to obtain design information and further verify erosion. Table 1 can be used as a guide. The three primary factors to assess are the erosion process, nearshore bathymetry, and whether there is marine plant access. In some cases, evidence of erosion isn't apparent, especially on low banks or when reconnaissance is done later in the summer when vegetation covers the bank. Most erosion sites will score at least a 15 on Table 1, however exceptions occur.

STEP 3 - Determine stabilization options using Tables 2 or 3 for natural or artificial shorelines. The stabilization options given are based on the factors of erosion process, nearshore bathymetry, and marine plant access. This table was developed based on bank stabilization jobs constructed or designed in the St. Paul District between 1987 and 1996 (See last column of Tables 2 and 3 for reference sites).

STEP 4 - Tables 4 through 8 list the reference sites used to compile Tables 2 and 3. Design drawings and documents for these reference sites can be found in St. Paul District files or by contacting hydraulics section personnel.

Table 1 - Erosion Conditions Assessment

EROSION PROCESSES		POSSIBLE SCORE	SCORE
River Currents	None	0	
	< 3 fps	5	
	> 3fps	10	
Wind Fetch	< 0.5 mile	0	
	0.5 to 1.0 mile	5	
	> 1.0 mile	10	
Navigation Effects	Minimal	0	
	Rec./Com.. Waves	3	
	Tow Prop Wash	10	
Ice Action	None	0	
	Possible Ice Action	3	
	Bank Displacement	10	
GEOMETRY/TOPOGRAPHY/BATHYMETRY			
Bends	Inside	0	
	Outside	5	
Shoreline Geometry /Orientation	Perpendicular to Wind	0	
	Not Perpendicular to Wind	2	
	Convex Shape	5	
Nearshore Depths	< 3 feet	0	
	> 3 feet	3	
VEGETATION			
Nearshore Vegetation	Persistent Emergents	0	
	Emergents	1	
	Submerged/No Vegetation	3	
Bank Vegetation	Dense	0	
	Sparse	1	
LOCAL SEDIMENT TRANSPORT			
Sediment Source	Upstream Source	0	
	No Source	1	
BANK MATERIAL			
Soil Type	Hard Clay/Gravel/Cobbles	0	
	Sand, Fines	1	
TOTAL SCORE			

Total Score > 15 Bank Stabilization Needed
Total Score < 15 Bank Stabilization Need is Questionable

Table 2 - Stabilization Designs used on Natural Shorelines.

Erosion Process	Nearshore Bathymetry	Marine Plant Access	Stabilization Design	Reference Sites
RIVER CURRENT	DEEP (> 3')	YES	Revetment 32"	A1,A2,A3,A4,A5,A6, A7,A8,A9, A12,A17,A19
		NO	Revetment 32"	A10
	SHALLOW (< 3')	YES	Rock Mound Rock Wedge	B1,B3,B4,B9 C4,C8
		NO	Rock Mound Rock/Berm/Bio	B6,B10,B13,B14 E1,E2,E3
WAVE ACTION	DEEP (> 3')	YES	See Note 1.	None
		NO	See Note 1.	None
	SHALLOW (< 3')	YES	Rock Wedge	C7
		NO	Rock Mound Rock Wedge	B2,B5,B7,B11 C2,C6

Note: 1. Natural shorelines eroded by wave action typically have shallow nearshore bathymetry.

2. Groins are not usually an option on natural shorelines because of the erosion that occurs while the shoreline adjusts to the groin field.

3. If river currents are the primary erosive force, and nearshore bathymetry is shallow, 18-inch or 32-inch revetments usually aren't considered an option because the toe of the revetment is subject to erosion after the bank is stabilized.

Table 3 - Stabilization Designs used on Artificial Shorelines

Erosion Process	Nearshore Bathymetry	Marine Plant Access	Stabilization Design	Reference Sites
RIVER CURRENT	DEEP (> 3')	YES	Revetment 18" Rock Groins	A15,A20 D5
		NO	Revetment 18"	None
	SHALLOW (< 3')	YES	Rock Groins Rock/Berm/Bio	D11 E10
		NO	Revetment 18" Rock Groins Rock Wedge Rock/Berm/Bio	A13,A16,A18 D1 C1 E6
WAVES	DEEP (> 3')	YES	Revetment 18" Rock/Berm/Bio	A11 E4
		NO	Revetment 18" Rock Groins	None D10
	SHALLOW (< 3')	YES	Rock Groins Rock Wedge	D2,D4,D6,D9 C3,C5
		NO	Revetment 18" Rock Groins Rock Mound Rock Wedge Rock/Berm/Bio	A14,A16 D3,D7,D8 B8,B12 None E5,E6,E7,E8,E9

Bank Stabilization Site List, 1987-1996

Table 4. Revetments Constructed Between 1987 and 1996.

Site	Rock Slope	T (in)	Rock Height (feet)	10-YR Flood Height (feet)	Geo-textile	Site Ref. #
Betsey Slough	1V:2.5H	30	4.0	8.5	No	A1
Billy's Slough	1V:1.5H	32	3.0	12.0	No	A2
Dakota	1V:2H	32	2.5	5.0	No	A3
Dresbach	1V:2H	32	4.5	4.5	No	A4
Duck Lake Chute	1V:1.5H	32	3.0	8.0	No	A5
Island 91	1V:2.5H	32	4.0	5.5	No	A6
Lansing Big Lake	1V:2.5H	36	4.0	8.0	No	A7
McMillan Island	1V:1.5H to 1V:2H	32	3.0	8.0	No	A8
Minneiska	1V:2H	36	1.0	3.5	No	A9
Murphy's Cut	1V:3H	30	3.0	6.5	No	A10
Onalaska Islands	1V:3H	18/27	5.0	4.0	Yes	A11
Polander Lake	1V:1.5H to 1V:3H	32	3 - 5	8.5	No	A12
Pool 8,P1 Boomerang Grassy Horshoe	 1V:3H 1V:3H 1V:3H	 18/27 18/27 18/27	 4.5 2.5 4.5	 4.5 4.5 4.5	 Yes Yes Yes	 A13 A14 A15
Pool 8 Phase 2	1V:3H	18/27	4.5	4.5	Yes	A16
Richmond Island	1V:2.5H	32	3.5	7.5	No	A17
Spring Lake	1V:3H	18/27	5.0	4.5	Yes	A18
Trempealeau Daymark	1V:2H	32	4.0	5.5	No	A19
Willow Island	1V:2.5H	18/27	2.0	7.0	Yes	A20

Table 5. Offshore Rock Mounds Constructed Between 1987 and 1996.

PROJECT	Rock Back Slope	Top Width (feet)	Rock Front Slope	Rock Height (feet)	10-yr Flood Height (feet)	Site Ref. #
Billy's Slough	1V:1.5H	5	1V:1.5H	3.0	12.0	B1
Brice Prairie	1V:1.5H	3	1V:3H	4.0	4.0	B2
Duck Lake Chute	1V:1.5H	3	1V:1.5H	3.0	8.0	B3
East Ch.	1V:1.5H	5	1V:1.5H	3.0	11.0	B4
East I.	1V:1.5H	3	1V:1.5H	3.0	4.5	B5
Heron I.	1V:1.5H	3	1V:1.5H	3.0	4.5	B6
Kiep's I.	1V:1.5H	3	1V:2.5H	3.0	6.0	B7
Mallard I	1V:1.5H	3	1V:1.5H	2.5	4.0	B8
McMillan Island	1V:1.5H	3	1V:2H	3.0	8.0	B9
Peterson Lake	1V:1.5H	3	1V:1.5H	2.5	4.0	B10
Pol. Lake Breakwat.	1V:1.5H	3	1V:3H	4.5	8.5	B11
Swan I.	1V:1.5H	3	1V:1.5H	3.0	4.0	B12
Trapping Island	1V:1.5H	3	1V:1.5H	3.0	4.5	B13
Tremp. Daymark	1V:1.5H	3	1V:1.5H	4.0	5.5	B14

Table 6. Rock Wedges Constructed Between 1987 and 1996.

Project	Top Width (feet)	Rock Slope	Rock Height (feet)	10-yr FL Height (feet)	Site Ref. #
Boomerang Island	10	1V:3H	4.5	4.5	C1
Brice Prairie	4	1V:2H	4.0	4.0	C2
Mallard I	2	1V:3H	4.0	4.0	C3
McMillan Island	5-15	1V:2H	3.0	8.0	C4
Onalaska Islands	4	1V:2H	3.0	4.0	C5
Polander Lake	3	1V:3H	2.5	6.0	C6
Red Oak I	10	1V:4H	4.0	4.0	C7
Spring Lake	10	Angle of Repose	2.5	4.0	C8

Table 7. Rock Groins Constructed Between 1987 and 1996.

Project	Top Width (feet)	Rock Slope	Rock Height (feet)	Groin Length (feet)	Groin Spacing (feet)	Site Ref. #
Dresbach Island	3	1V:1.5H	3	30	120	D1
East Island	3	1V:1.5H	2	30-40	100 & 170	D2
Grassy I.	2	1V:2H	1.5	30	100 - 150	D3
Mallard Island	3	1V:1.5H	1.5	30	150	D4
MN-10	5	1V:2H	2	55	100 - 150	D5
Onalaska Islands	5	1V:1.5H	2	30	150	D6
Pool 8 Phase 1	2	1V:2H	1.5	30	180	D7
Spring Lake	3	1V:1.5H	2	20	100 - 120	D8
Swan Island	3	1V:1.5H	1.5	30 45	150 - 270 180	D9
Tremp NWR	3	1V:1.5H	2	30	150	D10
Willow Island	3	1V:1.5H	2.5	30	150	D11

Note: 1. Groin length given above is the measured from the shoreline to the end of the groin. Usually groins are keyed into the shoreline 5 to 10 feet.

Table 8. Rock/Berm/Biotechnical Combinations Constructed Between 1987 and 1996.

Project	Berm Width (feet)	Berm Height (feet)	Type of Rock Protection	Willows Planted	Site Ref. #
Dresbach Island	20	2-4	Revetment 32" Groins	No	E1
East Channel, Pool 7	30	0.5	Revetment 36"	Yes	E2
McMillan Island	20-150	2	Revetment 32"	Yes	E3
Onalaska Islands	20	3	None	No	E4
Pool 8,Ph 1 Boomerang Boomerang Horshoe	 30 30 50	 2-2.5 2-2.5 0-2	 Groins None None	 Yes Yes No	 E5 E6 E7
Pool 8,Ph 2	30	2	Groins/None	Yes	E8
Spring L.	30	2	Groins	No	E9
Willow Island	30	2.5	Groins	Yes	E10

Note: 1. Berm Height is measured from the average water surface elevation.

2. Table 9 lists the function of each component of the rock/berm/biotechnical design.

Table 9. Rock/Berm/Biotechnical Stabilization Components.

COMPONENT	FUNCTION
Rock	Stabilize berm
Berm	Function 1 - Provide sand for beach formation Function 2 - Provide substrate for woody vegetation growth Function 3 - Provide habitat diversity
Willows	Stabilize Island

DESIGN NOTES

1. Two types of rock revetments are currently used: Revetment 1 (Graded Riprap, 18 inches thick, 1V:2.5 to 3H side slope, with geotextile fabric) is used on new construction such as islands or dikes. Revetment 2 (Rock Fill, 32" thick, 1V:1.5H to 1V:3H side slope) is used on existing shorelines which have variable slopes. The greater thickness of revetment 2 prevents piping of bank material, so no filter is required. Revetment 1 has been used in shallow water situations. This causes some concern over toe scour, however by increasing the rock layer thickness by a factor of 1.5 (to 27 inches) much of this concern is alleviated.

2. Rock groins are used mainly on new construction in shallow water where wave action and littoral drift are the dominant processes. After groins are constructed, shoreline reshaping occurs with deposition ocurring updrift of groins and erosion ocurring downdrift of groins. This continues until a stable scalloped shape is formed. The erosion that occurs is usually acceptable on new construction, but isn't acceptable on natural shorelines. The advantage of groins is cost savings (if in shallow water), creation of littoral and beach habitat, and an aesthetically pleasing shoreline. The ratio of groin spacing to groin length varies from 4 to 6 for habitat projects. The height of rock groins varies from 1.5 to 3 feet above the average water surface.

3. Off-shore Rock Mounds are used on natural shorelines in four situations

- shorelines with shallow nearshore bathymetry which prevents access by marine plant.
- low shorelines or marsh areas where there is not a well defined shoreline (ie. river bank)
- shorelines with shallow nearshore bathymetry where it is desireable to get the outside toe of the rock into deeper water to prevent undercutting.
- shorelines with heavy woody debris (overhanging or fallen trees, logs, etc.). It is sometimes easier and desireable from a habitat standpoint to leave the shoreline untouched and simply build an offshore rockmound.

There are only a couple instances where offshore rock mounds have been used on artificial shorelines. On new construction, where shoreline access (marine or land-based) is readily available, offshore rock mounds are difficult to justify economically. In the two cases where rock mounds were used on artificial shorelines, the islands were over 5 years old, and a shallow nearshore beach had formed, which limited access and reduced the overall rock height.

4. Rock/Berm/Biotechnical stabilization is widely used to stabilize new construction in moderately erosive areas. Usually rock groins are used, but rock revetments or wedges have also been used. Woody vegetation establishment can rely on natural succession, however investing in woody plantings advances growth by 2 or 3 years, which is usually a good investment.

5. Vegetative Stabilization consisting of willow plantings, wattles, brush mats, etc. are used in areas where erosive forces are low. Usually wind fetches are less than 0.5 miles, river currents < 3 fps, and offshore areas are shallow. Table 10 lists sites where vegetative stabilization has been used.

Table 10.Vegetative Stabilization Constructed Between 1987 and 1996.

Project	Biotech	Rock Used	Success
Grassy I.	Wattles/ Brush Mats	No	Yes
Island 42	Plantings, Snow Fence, Logs	No	No
Mallard I., 1992	Brush Mats, Wattles, Fiber Rolls	Yes	Yes
Swan I., 1987	Snow Fence, Plantings	No	No
Swan I., 1996	Brush Mats, Fiber Rolls	No	Yes

6. There have been no bank stabilization failures (failure defined as threatening project purpose) involving rock during the 10 year time period looked at here. Instances where rock displacement has been observed include:

- Lake Onalaska Islands during the Spring breakup in 1994. Winds in excess of 30 mph drove ice sheets into the islands causing significant displacement of revetment.
- Pool 8 Islands, where 50 to 60 mph sustained winds displaced smaller rocks during the flood of 1993.